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2012

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citation for published version (APA)

Giannakopoulos, G. F. (2012). *Triage and assessment of injuries in early trauma care*. [PhD-Thesis - Research and graduation internal, Vrije Universiteit Amsterdam].

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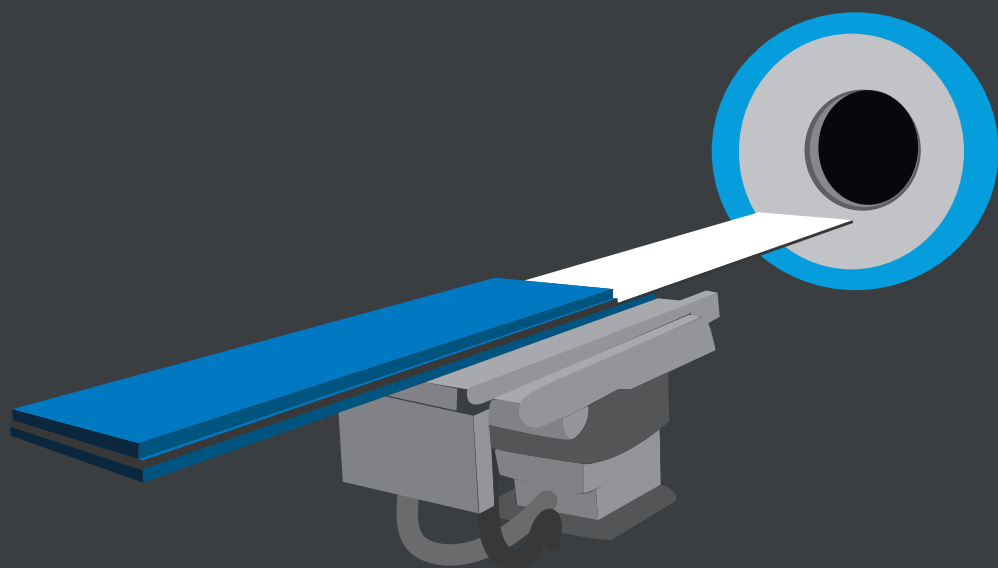
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Do tertiary surveys reduce missed injuries? A systematic review and meta-analysis

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Submitted

ABSTRACT

Background

Tertiary surveys (TSs) are often advocated for reducing missed injuries in hospitalized trauma patients. The aim of this study was to systematically review the evidence for whether tertiary surveys improve trauma care by reducing the missed injury rate in trauma patients.

Methods

An electronic search (without language or publication restrictions) of the Cochrane Library, Medline and Ovid was used to identify studies assessing TSs with short-term measures of missed injuries and long-term health outcomes. 'Missed injuries' were defined as either any injury: 1) missed at primary and secondary survey and detected by TS; or 2) that escaped detection by TS. Two authors independently selected studies. The risk of bias of was assessed using the Newcastle-Ottawa scale for observational studies.

Results

Ten observational studies met our inclusion criteria, (none were randomized), and had variable risk of bias. Three studies reported outcome data on missed injuries for both intervention and control cohorts. Meta-analysis was performed by missed injury definition. TSs lead to increased detection of injuries missed at initial assessment, (OR 2.82; 1.02-7.78, $P = 0.04$) with considerable heterogeneity ($I^2 = 81\%$, $P = 0.02$). Only one study reported a decrease in missed injuries not detected by TS (OR 0.66; 0.44-0.90, $P < 0.01$). No studies reported outcome data on long-term health outcomes.

Conclusion

Routine tertiary surveys may improve trauma care, either by increasing detection of injuries missed during initial management including the first 24 hours, or by decreasing missed injuries as a result of TS performance. This evidence is based on few studies. There is a lack of consistent outcome definitions, moderate risk of bias inherent to observational studies, and absence of long-term outcomes. Future studies should address these shortcomings. A general classification for missed injuries is made.

INTRODUCTION

The assessment and management of severely injured trauma patients in the Emergency Department (ED) is time-critical and complex. Life- and limb-threatening injuries must be identified and treated urgently. Altered level of consciousness (from central nervous system injury, intoxication or sedation), distracting injury, or need for emergent surgery may result in patients being unable to indicate all their injuries. Such urgent initial examinations, necessarily incomplete, may lead to injuries going undetected past the time when their management would avoid morbidity¹⁻¹² or even mortality.^{3,5,6,7,13,14}

The tertiary survey (TS) has been proposed to address this problem in admitted trauma patients. It should follow the episode of emergency care and may include a comprehensive general physical re-examination and review of all investigations, including diagnostic imaging and blood results, within 24 hours,^{6,9,10} and again when the patient is conscious, cooperative and mobilised.^{1,6,11}

The most commonly used definition of *missed injury* refers to the injuries missed at initial assessment up to 24 hours (including both primary and secondary survey and emergency intervention).^{1,10,11} With the TS becoming part of standard trauma care, another definition refers to injuries missed *after* TS performance.⁹ The effect of a TS on missed injuries will depend on which definition is used, with expected increase in detected injuries using the former definition, but decrease in missed injuries if utilizing the latter.

The TS should, by simple intuition, improve trauma care. The variation of the definition of missed injury may confuse interpretation of results, and any benefits might be outweighed by excessive use of resources, or over-diagnosis (in which a TS-identified injury has little or no effect on clinically relevant, long-term outcomes).¹⁵

To test this empirically, we conducted a systematic review of the literature to determine the effect of the TS in hospitalized trauma patients on the primary outcome of missed injury rates assessing both definitions 1) missed injury at initial assessment – detected by TS, 2) missed injury – escaped detection by TS. Secondary outcomes included long-term health outcomes.

PATIENTS AND METHODS

Our review adheres to the PRISMA statement (www.prisma-statement.org).

Study eligibility

We considered all study types assessing a TS using randomized or quasi-randomized trials, observational studies such as cohort, case-control and before-and-after design studies. Subjects were trauma patients admitted to any hospital, with no limits regarding age, gender, or severity of trauma.

We included any study that used the introduction of a TS as an intervention, either alone, or as part of a larger intervention (e.g. change in hospital trauma system). The TS had to be defined as a review of the admitted patient within 24 hours (or after regaining consciousness) and include at least a repeat of a head-to-toe examination. Outcome measures had to include either the primary or secondary outcome, missed injury rate or long-term health outcomes, respectively. Missed injury was defined as either 1) any injury missed at initial management (primary and secondary survey and emergency intervention) and detected by TS, or 2) any

injury that escaped detection by TS. The missed injury rate was the proportion of patients with a missed injury within the study population. Long-term health outcomes included rates of injuries detected after hospital discharge and ability to return to pre-injury functional status.

Search strategy and information sources

Relevant studies were identified using electronic searches of MEDLINE (1966 to December 2010) and OVID (1980 to December 2010) and the Cochrane Library Central Registry of controlled trials, without language restrictions, (Box 1).

Box 1. Search Strategy (December 2010)

1. exp Diagnostic Errors/
2. (missed adj2 diagnosis).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
3. exp "Outcome and Process Assessment (Health Care)"/
4. (missed adj1 injur\$).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
5. (delayed adj1 diagnosis).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
6. (prognostic adj1 outcome\$).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
7. exp treatment outcome/
8. (long adj1 term adj1 outcome\$).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
9. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8
10. exp Emergency Service, Hospital/
11. exp Emergency Medical Services/
12. Emergencies/
13. exp Emergency Treatment/
14. exp Critical Care/
15. Traumatology/
16. exp "Wounds and Injuries"/
17. trauma.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
18. 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17
19. Medical History Taking/
20. data collection/ or health surveys/ or questionnaires/
21. (trauma adj1 system\$).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
22. (tertiary adj1 survey\$).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
23. tertiary trauma survey\$.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
24. (trauma adj1 survey\$).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
25. (primary adj1 survey\$).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
26. (secondary adj1 survey\$).mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
27. survey\$.mp. [mp=title, original title, abstract, name of substance word, subject heading word, unique identifier]
28. trauma severity indices/ or injury severity score/
29. 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28
30. 9 and 18 and 29
31. 9 or 18 or 29

Selection of studies

Two reviewers (GK and GG) independently assessed all titles and abstracts for potential relevant articles. Any disagreement was adjudicated by a third reviewer (LG). We retrieved the full-text article of any reference that appeared to meet the inclusion criteria. The eligibility of the full-text articles was assessed with a standardized form.

Data extraction and management

The following data were extracted from the studies: title, year of publication, country of study, study design, number of participants, age and gender of participants, injury severity score (ISS), mechanism of trauma (blunt vs. penetrating), presence of an altered level of consciousness and admission to intensive care unit (ICU). The outcome parameters on missed injury rates and long-term outcomes were collected when available. When necessary, authors were contacted in order to obtain relevant information missing from full-text articles. Where possible, we used meta-analysis to quantify and summarize results. We calculated the I^2 statistic for each pooled estimate to assess the impact of statistical heterogeneity.¹⁶⁻¹⁷ Primary and secondary outcomes were all proportions. For studies that only reported outcomes on a single cohort (without comparison cohort) and could not be included in the meta-analysis we used simple weighted averages to pool results. For studies where comparison cohorts were available, we carried out a quantitative analysis and summarised the effect of the TS as an odds ratio (OR) with 95% confidence intervals (95% CI).

Since we anticipated possible differences in outcomes for certain demographic groups, we defined potential subgroups for analysis *a priori*, which included; age, gender, ISS (either continuous or using 15 as cut-off), injury mechanism (blunt vs. penetrating), altered level of consciousness and ICU admission.

Assessment of risk of bias

The Newcastle-Ottawa Scale¹⁸ for non-randomized observational studies was used to assess the quality of the included studies. This occurred independently by two authors (GK and GG). This scale (Box 2) reflects the quality of the methodology. The number of items that were assessed to be inadequate on this scale reflected the degree of risk of bias. We classified studies either at low, moderate or high risk of bias if there were respectively up to 1, 2-3 or >3 items inadequate.

RESULTS

Our search identified a total of 4 659 of potentially relevant references. We discarded 4 615 after examining their Title or Abstract. The full-text articles of the remaining 44 were retrieved: 10 studies^{1, 9-11, 19-23} were included in the review, (of which three were considered for meta-analysis, Figure 1; Table 1). None were randomized or pseudo-randomized trials, meaning all 10 included studies were observational, (seven prospective cohort studies^{6, 10-11, 20-23}, one prospective cohort study with historical comparison¹; and two cohort studies with a before-and-after design^{9, 19}).

Their risk of bias, as assessed by the Newcastle-Ottawa scale, was low in two studies and moderate in the remaining eight (Table 1). The selection of participants in all studies was by consecutively admitted trauma patients, ensuring appropriate representativeness and minimizing selection bias. They all used either the medical records or a special form to

Box 2. Newcastle-Ottawa Scale for cohort studies

Selection

1) Representativeness of the exposed cohort

- a) truly representative of the average admitted trauma patient *
- b) somewhat representative of the average admitted trauma patient *
- c) selected group of users e.g. nurses, volunteers
- d) no description of the derivation of the cohort

2) Selection of the non exposed cohort

- a) drawn from the same community as the exposed cohort*
- b) drawn from a different source
- c) no description of the derivation of the non exposed cohort

3) Ascertainment of exposure

- a) secure record (e.g. surgical records) *
- b) structured interview *
- c) written self report
- d) no description

4) Demonstration that outcome of interest was not present at start of study

- a) yes *
- b) no

Comparability

1) Comparability of cohorts on the basis of the design or analysis

- a) study controls for Injury severity *
- b) study controls for any additional factor * (Age, gender, type of mechanism, altered level of consciousness, admission to ICU)

Outcome

1) Assessment of outcome

- a) independent blind assessment *
- b) record linkage *
- c) self report
- d) no description

2) Was follow-up long enough for outcomes to occur

- a) yes (select an adequate follow up period for outcome of interest) *
- b) no

3) Adequacy of follow up of cohorts

- a) complete follow up - all subjects accounted for *
- b) subjects lost to follow up unlikely to introduce bias - small number lost - > <20% loss to follow up, or description provided of those lost) *
- c) follow up rate <80% and no description of those lost
- d) no statement

* appropriate method

determine whether a TS had occurred. Seven studies did not have a comparison cohort (i.e. cohort without TS performed), increasing their risk of bias.

There was insufficient information to assess the comparability section of the Newcastle-Ottawa scale for eight studies. The remaining two studies^{9,19} had comparable demographics for exposed and non-exposed cohorts, except for a higher admission rate to the trauma ICU in the cohort receiving the TS compared to those in the cohort who had routine care (30% vs. 20% admission rate) in one study⁹, suggesting a possible change in trauma care or admission criteria.

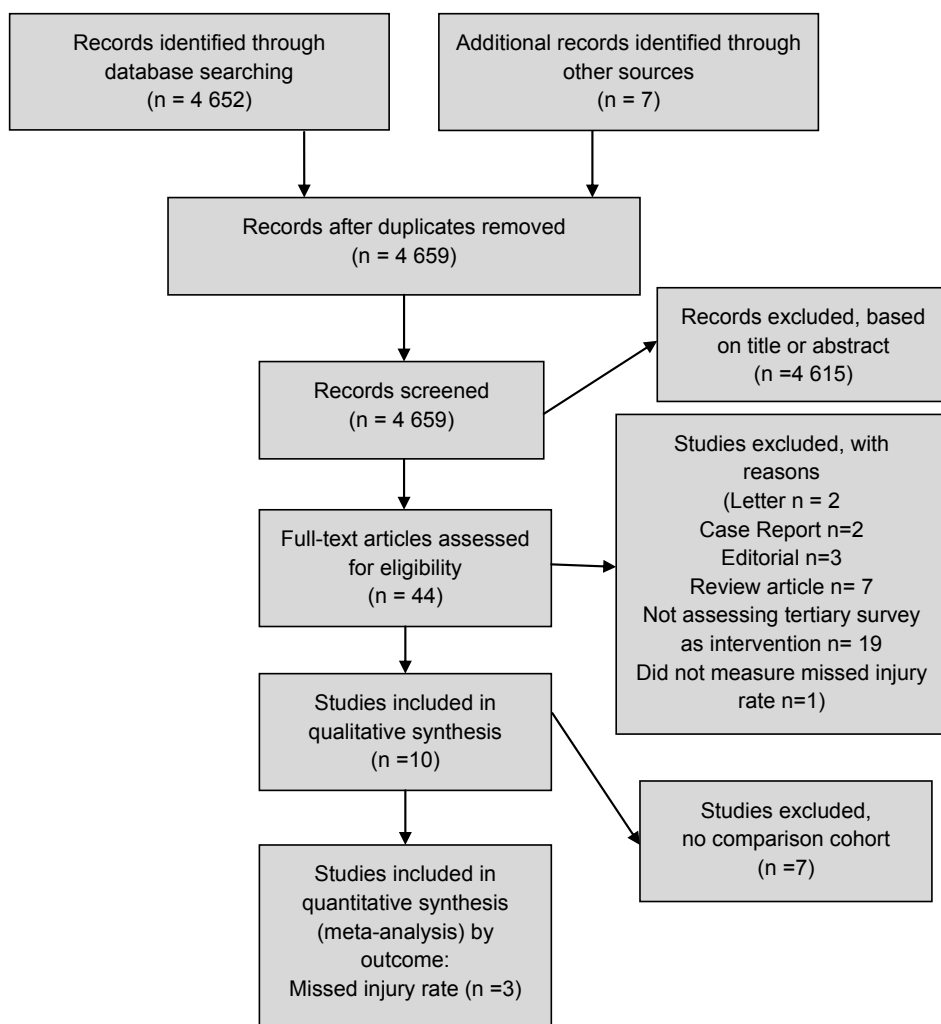


Figure 1. Selection of studies

Missed injury rate after TS introduction

Nine^{1, 10-11, 19-23} of the included studies used the first definition of missed injury (missed at primary and secondary survey and detected by TS), with the remaining single other study⁹ utilizing the second definition (injury missed by the TS).

For the first definition, the overall missed injury rate in cohorts with a TS conducted was 4.3% (*Table 3a*). The two largest studies^{10, 21} had similar missed injury rates (1.3% and 1.6%, respectively), while a medium-sized study¹⁹ had a missed injury rate of 6.2% (unpublished data provided by author). The remaining studies reported missed injury rates varying from 9.3 to 19.3%, with one small study⁶ being an outlier (65%). In this study, a dedicated trauma surgery fellow aware of the purpose of the study performed all tertiary surveys.

Table 1. Description of included studies

Author, year	Population	Intervention	Outcome measure	Study Design
Enderson, 1990	399 admitted trauma patients	TS as part of trauma admission form, conducted within 24-48 hours after patient stabilization	Missed injuries – defined as detected during or after tertiary survey.	Prospective cohort study – comparing with historical summary data
Biffi, 2003	All admitted trauma patients. Before: 3412, after: 3442	Implementation of formal TS, using standardized form and TS policy. TS within 24 hours and after ICU discharge	Missed injury rate – defined as injuries detected after 24 hours admission or injuries missed by TS.	Cohort study with before-and-after design
Vles, 2003	All (3879) admitted trauma patients	Use of standard trauma forms, TS and review of radiology within 24 hours	Missed injury rate – Any injury missed on primary and secondary survey	Prospective cohort study
Hoff, 2004	432 admitted trauma patients	Formal radiology rounds as part of TS	Missed injury or ‘new diagnosis’ as result of radiology rounds with trauma surgeons.	Prospective cohort study
Soundappan, 2004	76 children admitted with ISS>9	TS performed using standardized form by trauma fellow on day after admission and after extubation.	Missed injury rate – Any injury missed on primary and secondary survey	Prospective cohort study
Howard, 2006	90 admitted trauma patients	TS performed using standardized form by single clinician within 4 hours	Missed injury rate – Any injury detected on the tertiary survey	Prospective cohort study
Okello, 2007	403 admitted trauma patients	Daily physical examination up to 30 days, including tertiary survey in first 24 hours.	Missed Injury – unclear definition – implied as injury detected after primary and secondary survey	Prospective cohort study
Janjua, 2008	206 admitted trauma patients	TS performed by trauma fellow within 24 hours and after regaining consciousness	Missed injury rate – Any injury missed on primary and secondary survey and operating room	Prospective cohort study
Ursic, 2009	All admitted trauma patients. Before: 981, after: 1006	Implementation of a dedicated trauma service, which included a formalised TS	Mortality and Length of Hospital stay. Missed injury – not in article - data retrieved via direct author communication - defined as any injury missed at primary and secondary survey	Cohort study with before-and-after design
Huynh, 2010	5143 admitted trauma patients	Mid level providers performed a TS using a form within 48 hours. This was reviewed by trauma surgeon	Missed injury – defined as detected at tertiary survey	Prospective cohort study

ISS: Injury Severity Score; TS: Tertiary Survey

Table 2. Risk of Bias of included studies

Author, year	Selection (max 4 items)	Comparability (max 1 item)	Outcome (max 3 items)	Comments
Enderson, 1990	1 – no description of non-exposed cohort	1 – no description of non-exposed cohort, just summary statistic given	0	Total score: 2 - Moderate risk
Biffi, 2003	0	0 – all demographic variables comparable in both cohorts	0	Total score: 0 - Low risk
Vles, 2003	1 – no description of non-exposed cohort	1 – no description of non-exposed cohort	0	Total score: 2 - Moderate risk
Hoff, 2004	1 – no description of non-exposed cohort	1 – no description of non-exposed cohort	0	Total score: 2 - Moderate risk
Soundappan, 2004	1 – no description of non-exposed cohort	1 – no description of non-exposed cohort	0	Total score: 2 - Moderate risk
Howard, 2006	1 – no description of non-exposed cohort	1 – no description of non-exposed cohort	0	Total score: 2 - Moderate risk
Okello, 2007	1 – no description of non-exposed cohort	1 – no description of non-exposed cohort	0	Total score: 2 - Moderate risk
Janjua, 2008	1 – no description of non-exposed cohort	1 – no description of non-exposed cohort	0	Total score: 2 - Moderate risk
Ursic, 2009	0	0 – all demographic variables comparable in both cohorts	0 – No missed injury description in article. Obtained through author communication	Total score: 0 - Low risk
Huynh, 2010	1 – no description of non-exposed cohort	1 – no description of non-exposed cohort	0	Total score: 2 - Moderate risk

Risk of Bias using Newcastle Ottawa Scale.¹⁸**Table 3.** Outcomes - Missed injury rates of included studies

	PRE Tertiary Survey implementation			POST Tertiary Survey implementation		
	Missed injuries	Study population (N)	Missed injury rate (%)	Missed injuries	Study population (N)	Missed injury rate (%)
Enderson, 1990			2.0	37	399	9.27
Biffi, 2003	81	3 412	2.37	52	3 442	1.51
Vles, 2003				49	3 879	1.26
Hoff, 2004				42	432	9.72
Soundappan, 2004				12	76	15.8
Howard, 2006				12	90	13.3
Okello, 2007				78	403	19.4
Janjua, 2008				134	206	65.0
Ursic, 2009	35	981	3.57	62	1 006	6.16
Huynh, 2010				80	5 143	1.56
Overall	116	4 393	2.64	558	15 076	3.70

Missed injury rate: before and after introduction of TS

Since two studies^{1,9} used the definition of missed injury at initial assessment (and detected by TS) and the remaining study⁹ used the second definition (injury missed by TS examination). Meta-analysis was performed for the two studies reporting the first definition of missed injury rates before and after introduction of TS using a random effects model. *Figure 2a* shows the forest plot with a summary OR of 2.82 (95% CI 1.02-7.78, $P = 0.04$) with considerable heterogeneity ($I^2 = 81\%$, $P = 0.02$). Only one study used the second definition (*Figure 2b*) *Subgroup analyses*

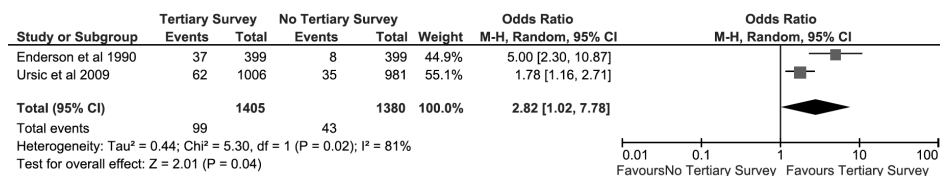


Figure 2a. Forest plot – Missed injuries at initial management (detected by TS)

Heterogeneity: $\tau^2 = 0.44$; $\chi^2 = 5.30$, $df = 1$ ($P = 0.02$); $I^2 = 81\%$; Test for overall effect: $Z = 2.01$ ($P = 0.04$)

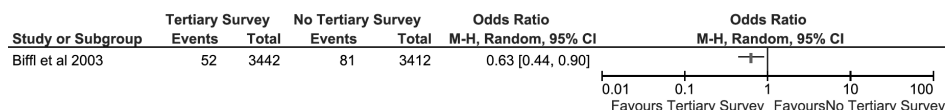


Figure 2b. Forest plot – Missed injuries that escaped detection by TS

No summary statistic or heterogeneity data since only one study included

One study only investigated a difference in missed injury rates after introduction of a TS for any of the pre-defined subgroups.⁹ It reported a decrease in missed injuries (that escaped detection by TS) in patients admitted to a trauma intensive care unit (5.7% vs. 3.4%, $p < 0.05$). Another reported a paediatric trauma population (missed injury rate at initial assessment: 15.8%), but did not specifically investigate age as a factor of interest.¹¹ A third study reported a lower mortality associated with a higher detection of missed injuries at TS, introduced as part of a trauma service.¹³

No other included study assessed differences in missed injury rate after introduction of a TS for the other pre-defined subgroups (age, gender, ISS, mechanism of injury or altered level of consciousness).

Long-term health outcomes

No studies that assessed the effect of the TS on long-term health outcome were identified

DISCUSSION

This systematic review found empirical evidence to confirm the proposition that the TS may improve trauma care by increasing early detection of injuries missed at initial assessment

and reducing injuries that escape detection at 24 hours by a TS or otherwise. This evidence was based on limited information – there were no randomized studies specifically looking at this question. Only few studies could be included in the meta-analysis, which was subject to heterogeneity.

The definition of missed injury amongst included studies was variable. Nine studies, including two eligible for meta-analysis, used ‘any injury missed by primary and secondary survey, and detected as a result of the TS’. Although most commonly used, this type of injury more so represents a delayed diagnosis (or increase in injury detection), especially in settings where repeat examinations at 24 hours are a more formalized part of standard trauma care. Only one study defined missed injury as any injury that escaped detection at time of the TS.⁹ The use of these differences in definition precludes overall comparison of studies and need to be made explicit in order to legitimately compare studies.

For example, in one study¹⁹ performing a TS increased the missed injury rate, but reported an associated reduction in mortality, which seems counter-intuitive. In light of the definition used, the missed injuries should be interpreted as an increased injury detection, which would be congruent with the mortality benefit.

Only observational studies with inherent risk of bias were available, with some heterogeneity. These can be summarised as shortcomings of variation in: the trauma patient populations (one study including paediatric trauma patients only¹¹; another conducted in Uganda²² where trauma patterns and trauma care may be different from those of the other studies); and in the intervention (which was differently defined in two, where one study²⁰ aimed to decrease missed injuries by formalizing the radiology review component of the tertiary survey, and the other¹⁹ assessed the effect of implementing a complete trauma service, which did include, but was not limited to, a TS).

The data for the two studies included in the meta-analysis (using missed injury rate at initial assessment, detected by TS) was not complete in the original publications. Enderson *et al*¹ quoted a historical *overall* missed injury rate of 2% (without data on sample size of this historical cohort) and Ursic *et al*¹⁹ did not report missed injury data in the published manuscript, but we obtained this information directly by personal communication.

This systematic review highlights several areas of interesting points. Firstly *missed injury* needs a consistent, clear and expanded definition. We suggest a classification of missed injuries that may help to clarify outcomes (Box 3). Especially the third group in this classification has likely been under-reported, since there is no published data on this.

Secondly, for the nine studies using ‘injuries missed at initial management and detected by TS’ a mean injury detection rate of 4.3% was found. This can be used as a yardstick to compare future studies assessing this type of missed injury. This may still be an over-estimation of missed injuries (or rather, delayed diagnoses), since the reported missed injury rate was approximately 1.5% in the two larger studies that together included more than 9 000 subjects and where investigator bias would have been minimal.

Lastly, it emphasizes the lack of studies reporting 1) long-term outcomes after a tertiary survey and 2) identifiers or risk groups that may benefit more from a TS. Studies have reported long-term outcomes for the multiple injured patients²⁴ or subgroups of patients with specific injuries.²⁵ However, no studies were identified that specifically reported the effect of a TS on the long-term outcomes. The lack of published data may be due to an assumed, intuitive, positive

Box 3. Missed injury classification

Missed injury type	Description
I	Before TS or as result of TS: Injury detected after primary and secondary survey and emergency intervention, but within 24 hours, before or through formal TS (i.e. delayed diagnosis at 24 hours)
II	After TS, during hospital stay: Injury detected in hospital after 24 hours, missed by TS.
III	After TS, after hospital discharge: Injury detected after hospital discharge (injury not detected during hospital stay including TS)

TS, Tertiary Survey

effect of the TS, although quantifying the actual effect on longer-term health outcomes may support a more structured and widespread use of the TS.

It is necessary to determine which patients would potentially benefit most from a TS. Although several studies have reported univariate predictors for missed injuries,^{6, 10-11, 20-22} the identified factors associated with missed injuries are likely correlated and interdependent (e.g. level of consciousness, blunt trauma and ISS). The study populations in which these analyses were conducted had a large variation in terms of injury severity, age and other demographics. Of these, none included the performance of the TS in the analysis as predictor for missed injuries.

LIMITATIONS

The questions we asked were specific, leading to few studies addressing them properly or at all. The risk of bias in most studies was moderate, and the absence of a comparison cohort in most studies limits the interpretation of this review, as does the paucity and heterogeneity of studies eligible for meta-analysis. We feel it is improbable that we have missed relevant studies and publication bias seems unlikely.

RECOMMENDATIONS

To further clarify the place of the TS in trauma care, we would like to make the following recommendations:

Firstly, a consistent use of the definition of *tertiary survey* is paramount. The tertiary survey is a complete re-examination of the patient, including review of all investigations including diagnostic imaging and pathology tests, within 24 hours of admission and when the patient regains consciousness and is cooperative.

Secondly, we propose future studies adhere to the classification of missed injury as suggested in Box 3. This future research needs to address the effect of a TS on long-term outcomes, which should include missed injuries detected after hospital discharge and functional outcomes such as time off work, time to return to pre-injury functional status.

Lastly, we recommend that future studies investigating the effect of the TS need to specifically aim to identify predictors of missed injuries, using appropriate statistical methodology, such as logistic or multivariate regression.

CONCLUSION

Tertiary surveys may improve trauma care, either by increasing detection of injuries missed at primary and secondary survey or by decreasing injuries missed after TS performance. However, the evidence on missed injury rates is heterogeneous and two different outcome definitions were used by the few studies eligible for meta-analysis. Many of the included studies failed to use appropriate comparison groups. Although randomized controlled studies may not be ethically justifiable, future studies need to use consistent outcome definitions and measure long-term outcomes, including missed injuries after hospital discharge.

ACKNOWLEDGEMENT

Assistant Professor Michael Steele for statistical advice.

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